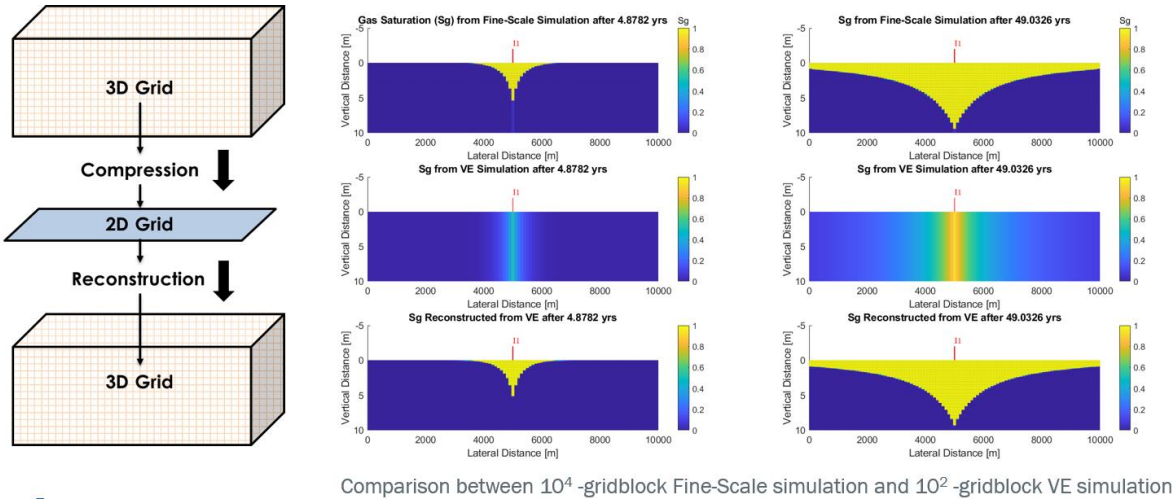
Topic - **Developing Vertical Equilibrium Models for Simulating CO_2 Storage in Depleted Gas Reservoirs**

The goal of this fellowship is to develop and establish vertical equilibrium (VE) models as a computationally efficient alternative for simulating CO2 storage in depleted gas reservoirs. The geological storage of captured CO2 in depleted gas reservoirs (storage potential of 500-1000Gt) offers a promising avenue for mitigating climate change. These reservoirs remain attractive options due to the potential to repurpose existing infrastructure and leverage geological knowledge gained during production. However, accurately predicting the fate of injected CO2 within these complex subsurface systems is essential for ensuring safe and effective storage. While full-physics reservoir simulators provide detailed insights, their computational demands can be prohibitive for large-scale assessments, uncertainty quantification or early-stage feasibility studies. This research will pave the way for wider adoption of VE models in large-scale CCS feasibility assessments, optimization studies, and risk mitigation strategies for depleted reservoirs.



Comparison between 10^4 -gridblock Fine-Scale simulation and 10^2 -gridblock VE simulation

Figure 1 – Illustration of plume evolution comparison between VE and 3D fine-scale simulation.

VE models are a well-established and powerful tool for CO2 storage in saline aquifers, with ongoing development and refinements taking place in the MuPhi Research Group and the global research community in large. The VE simplification allows for the reduction of the governing equations into a lower-dimensional system, significantly reducing computational complexity while maintaining physical accuracy (Figure 1). In this project, the student will advance methods for adapting VE simulation for depleted gas reservoirs in a way that accounts for the challenges that come from the mixing dynamics between CO2, resident natural gas, and brine. The student will develop the model within the open-source MRST (MATLAB Reservoir Simulation Toolbox) framework. More specifically, this research can be divided into the following objectives:

1) Develop a robust understanding of the multiphase flow dynamics in depleted gas reservoirs - The residual gas dramatically alter relative permeability of the injected and aqueous phase, with the gas phase relative permeability strongly dependent on the time-history of imbibition or drainage (Hysteresis). The student will implement appropriate relative permeability and capillary pressure models that account for the phase behaviour of CO2 in the presence of natural gas (CH4) and aqueous phase within a VE framework, ensuring reliable prediction of CO2 plume migration and saturation.
2) Represent gas mixing for VE Simulations: Mixing of CH4 with CO2 significantly decreases the gas mixture density and viscosity, impacting injectivity and mobility of the gas phase. The student will develop accurate representation of this process within VE framework for obtaining realistic predictions.
3) Robust VE models require thorough validation against benchmark datasets and full-physics simulations. The student will perform rigorous validation to ensure the reliability and interpretability of VE predictions. The developed VE models will be applied to case studies of CO2 storage in North Sea-based depleted gas reservoir settings.

Eligibility

1) This project is open to all students, whether home, EU or overseas.
2) The successful candidate will have at least an upper second-class (2:1) undergraduate degree in a relevant subject area and ideally a master's degree or evidence of significant relevant professional experience equivalent to master's level.
3) Applicants with a geomaterials/ physics/ applied geoscience/ civil engineering/reservoir engineering/Chemical Engineering or related qualification are preferred. Strong interest in computational, petrophysical, and thermodynamic methods are particularly encouraged.
4) Applicants should further have a strong motivation to succeed in scientific research, excellent presentation, coding skills and scientific writing skills as well as very good to excellent English language skills (verbally and written).
5) Scholarships will be awarded by competitive merit, considering the academic ability of the applicant. We particularly encourage female candidates to apply.
6) We recognise that not every talented researcher will have had the same opportunities to advance their careers. We therefore will account for any particular circumstances that applicants disclose (e.g., parental leave, caring duties, part-time jobs to support studies, disabilities etc.) to ensure an inclusive and fair recruitment process.

How to apply

1) To apply you must complete our online application form.
2) Please select **PhD GeoEnergy Engineering** as the programme and include the full project title, reference number and supervisor name on your application form. Ensure that all fields marked as 'required' are complete.
3) Once have entered your personal details, click submit. You will be asked to upload your supporting documents. You must complete the section marked **project proposal;** provide a supporting statement (1-2 A4 pages) documenting your reasons for applying to this particular project, outlining your suitability and how you would approach the project. You must also upload your CV, a copy of your degree certificate and relevant transcripts and an academic reference in the relevant section of the application form.
4) You must also provide proof of your ability in the English language (if English is not your mother tongue). We require an IELTS certificate showing an overall score of at least 6.5 with no component scoring less than 6.0, or a TOEFL certificate with an overall score of at least 85, including reading 20, listening 19, speaking 20 and writing 21. Alternatively, if you have received an English-taught Bachelors or Master's degree from one of the countries listed on the UK Government Guidance under 'Who does not need to prove their knowledge of English', and it was obtained less than two years from your intended start date, you should provide evidence of your award that clearly states it was delivered and assessed in English language.

Please contact the supervisory team for further information or an informal discussion: Prof Florian Doster, (f.doster@hw.ac.uk), Dr. Hariharan Ramachandran (h.ramachandran@hw.ac.uk) and Dr. Gang Wang (g.wang@hw.ac.uk)
Please contact egis-pgr-apps@hw.ac.uk for technical support with your application.

Timeline

The closing date for applications is **12 April 2024** and applicants must be available to start in September 2024.

Funding Notes

James Watt Scholarship
This is a full scholarship which will cover tuition fees (Home and Oversees) and provide an annual stipend (£19,237 in 2024-25) for 42 months. Thereafter, candidates will be expected to pay a continuing affiliation fee (currently £130) whilst they complete writing up their thesis.